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Effect of *Moringa oleifera*-alum Ratios on Surface Water Treatment in North East Nigeria

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Abstract: The aim of this study is to find out the optimum combination for MO and alum using alum as a coagulant aid in household treatment of natural pond surface water for domestic use. The physico-chemical properties investigated for in the raw, settled and filtered water were Ph, Total Dissolved Solids (tds), turbidity, colour and total suspended solids (tss). The various coagulant combinations with which the raw water from the pond was treated include *Moringa oleifera* (MO) seed powder only (i.e., 100% MO), aluminium sulphate (alum) only (i.e., 100% alum), 20% alum and 80% *Moringa oleifera* seed powder, 40% alum and 60% *Moringa oleifera* seed powder, 50% alum and 50% *Moringa oleifera* seed powder; 60% alum and 40% *Moringa oleifera* seed powder; and 80% alum and 20% *Moringa oleifera* seed powder. Five of the seven used coagulant combinations gave acceptable turbidity reduction i.e., below 10NTU. When *Moringa oleifera* seed powder was used as the sole coagulant, a filter was needed to obtain an acceptable turbidity value of 7.8NTU but there was no need for pH adjustment or correction. *Moringa oleifera* seed powder can be used in treating household drinking water either as a sole coagulant or in combination with alum (using the alum) as a coagulant aid. The settling time for the MO seed powder is longer than that of the combined coagulants if the same results are to be obtained. The recommended ratio for the combined coagulant dose is 60% MO seed powder and 40% alum.

Key words: Alum, coagulation, household filter, *Moringa oleifera* seed powder, turbidity

INTRODUCTION

Large populations in Africa have no access to clean drinking water making many people prone to water borne diseases such as cholera, typhoid, dysentery and diarrhea. This has claimed many lives in both rural and urban areas. The promotion and use of *Moringa oleifera* (MO) seed powder among the rural populations will contribute to improving living standards of vulnerable groups (the sick, the young and the aged) through the provision of clean drinking water (Nkhata, 2001). MO seed powder has been found to be an environmentally friendly, cheap and viable alternative to expensive conventional chemicals. It has traditionally been used for household water treatment in Sudan and Indonesia (Jahn and Hamid, 1979; Folkand and Sutherland, 1996). In Malawi it has successfully been used in place of conventional water treatment chemicals for colour; micro organisms and suspended solids removal in surface waters (NISIR, 1997). MO seed powder is a natural alternative to imported alum (aluminium sulphate, the conventional synthetic coagulant) used in purifying turbid water (Ayotunde *et al*., 2004). In a related research by Mbarara University of Science and Technology, the total amount of coliforms before and after clarification of water from the river Rwize of Uganda were assessed. The use of MO seeds in the process showed that this technology eliminated upto 99% of bacteria found in the water (VO, Minhqvo@ufl.edu).

Compared to the commonly used coagulant chemicals, MO has a number of advantages which include low cost production of biodegradable sludge, lower sludge volume and the fact that it does not affect the pH of the water under treatment. These qualities make MO a consumer and environmentally friendly low cost alternative with significant potential both in developing and developed countries (Ghebremichael, 2004). The water soluble MO seed proteins possess coagulating properties similar to those of alum and other synthetic cationic polymers (Mataka *et al*., 2006). The active agents of *Moringa oleifera* extract responsible for

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oagulation are dimeric cationic proteins with molecular weight of 13KDa and isoelectric points between 10 and 11 (Jahn, 1981; Ndabigengesere *et al*., 1995). Combination of the MO seed solution with aluminium sulphate reduces the amount of alum being used in water treatment and still gives good flocculation results. The use of aluminium sulphate can be reduced by 70% with sustained purification efficiency if it is combined with MO (Lilliehook, 2005). The aim of this study is to find out the optimum combination for MO and alum using alum as a coagulant aid in household treatment of natural pond surface water for domestic use.

Description of study area: Borno state of Nigeria is situated in the semi arid region of the country. The region has three major seasons - the rainy season between the months of June and September, the dry cold seasons (Harmattan) between the months of October and January, and the dry hot season between the months of February and May each year. The region in characterized by low temperatures during the harmattan and high temperatures up to 40ºC in the dry hot season. Water supply in the state in grossly inadequate and makes especially the rural dwellers source for water in most unusual places. One of the sources is the ponds. These facilities are entrenchments into the ground thereby creating a temporary storage reservoir for rain water harvesting. This source of water becomes very important in the long dry season that sets in after the short rainy season. The rural dwellers use this water for all aspects of domestic activities including watering animals which is a very important aspect of the socio-culture lives of the lives of the people in Borno State especially, the Fulani cattle rearers.

METHODOLOGY

This study was carried out in Borno State in the North Eastern part of Nigeria . Physicochemical and bacteriological tests were carried on the various water samples. The water to be treated was collected from a borrow pit at a place called Jimtillo at the outskirts of Maiduguri, the Borno State capital. The Moringa seeds used were collected during the dry season. The pods were unshelled and the seeds removed. The seed were later ground into powder and kept in a container with a cover. The alum which is to be used was brought from the store and pounded to give a powdery form.

In preparation of the sand filter, various sizes of aggregate were collected, including sharp sand, peanut size gravel, 19 mm size gravel and flat large stones. The various size of the aggregate were washed separately and put into the oven to kill bacteria in order not to increase the bacteriological content of the water to be treated. The 19 mm size gravels were first placed around the bored hole at the base. The peanut size gravel was arranged to a height of 15 cm next to the 19 mm gravel. This was followed by the sharp sand to a height of 25 cm above the level of the peanut sized gravel. Finally the flat stones were laid of the surface of the sharp sand to prevent the water from scouring the sand.

Water was added to 16000 mg of the *Moringa oleifera* (MO) seed powder (i.e., 800 mg per litre for 20 L or 100% MO). The suspension was shaken for one minute (1 min) to release the active coagulation ingredients and sieved into a bucket containing 20 L of turbid water. The mixture was stirred quickly for 30 sec and slowly for five minutes. The contents of the bucket was poured into a settling tank and allowed to settle for two hours without disturbing it under quiescent conditions. This procedure was repeated for the 100% alum (using only alum as the sole coagulant i.e., 16000 g of alum), 80% MO and 20% Alum, 60% MO and 40% Alum, 50% MO and 50% Alum, 40% MO and 60% Alum, 20% MO and 80% Alum. It should be noted that the stated percentages are by weight of 16000 g. For the 100% MO (i.e., using *Moringa oleifera* as sole coagulant) treatment the coagulant was left in contact with the turbid water for three hours before releasing the effluent into the sand filter.

After two hours and three hours respectively, the settled water was collected for bacteriological and physical tests. The bacteriological examination of the water samples was carried out according to Bacteriological Examination of Drinking Water Supplies (1979) while the physic-chemical tests were carried according to Environmental Chemistry Laboratory Manual (2000).

RESULTS AND DISCUSSION

Effect of coagulant and coagulant dose on physico-chemical properties: The physico-chemical properties investigated for in the raw, settled and filtered water were pH, total dissolved solids (tds), turbidity, colour and total suspended solids (tss). The various coagulant combinations with which the raw water from the pond was treated include *Moringa oleifera* seed powder only (i.e., 100% MO), aluminium sulphate (alum) only (i.e. 100% alum), 20% alum and 80% *Moringa oleifera* seed powder, 40% alum and 60% *Moringa oleifera* seed powder, 50% alum and 50% *Moringa oleifera* seed

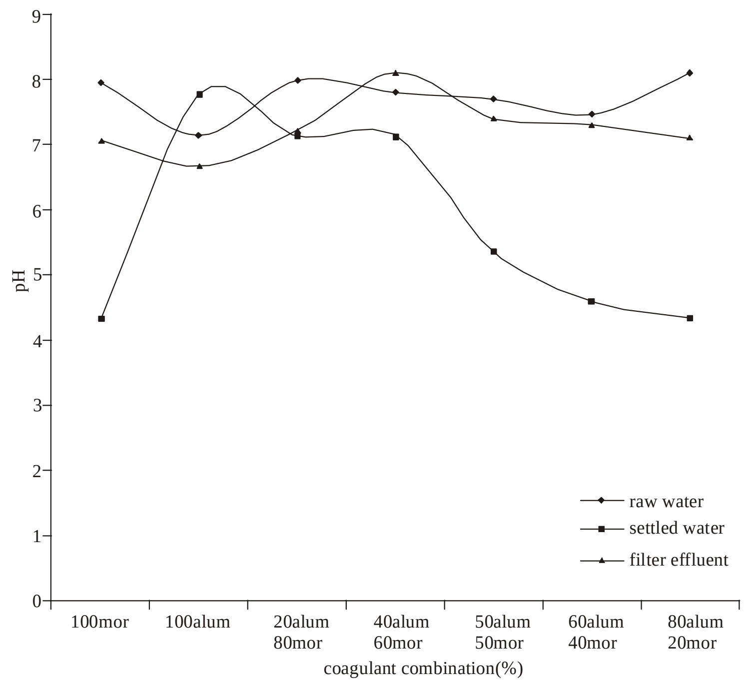

Fig. 1: Plot of pH against coagulant concentrations

powder; 60% alum and 40% *Moringa oleifera* seed powder; and 80% alum and 20% *Moringa oleifera* seed powder.

The pH value of the raw water ranged between 7.15 and 8.10. When the raw water with a pH of 7.95 was treated with 0.8 g/L of *Moringa oleifera* seed powder only (i.e., 100% *Moringa oleifera*) the pH dropped to only 7.76. This is in consonance with the results of Muyibi and Evison (1995) that showed that the pH of the water softened with MO seed powder was within the recommended WHO standards and independent of the *Moringa oleifera*. Also Katayon *et al*. (2004) indicated that MO seeds did not affect the pH value of water samples significantly although a slight decrease in pH was seen after the coagulation process of MO. Katayon *et al*. (2004) suggested that the decrease in pH when using MO seed powder may be due to hydrogen ions of the weak acidity of MO stock solution, which balances the hydroxide ions in the raw water.

The addition of alum to the water samples reduced the pH in the settled water below the WHO acceptable limit of 6.5 (WHO, 1996). When 800 mg/L of alum was added to the water, the pH reduced from 7.15 to 4.33. An alum concentration of 640 mg/L caused changes in the pH of the raw water from a value of 8.10 to a settled water value of 4.34. Various percentage combinations of aluminium sulphate and MO seed powder (Fig. 1) revealed drops in the pH value for the settled water to different degrees. When the quantity of MO seed powder was more than the quantity of alum in any water sample treated (i.e., 320 mg/L of alum with 480 mg/L MO; and 160 mg/L of alum with 640 mg/L of MO seed powder), the pH reduction was within the WHO approved range of 6.5 to 8.5 but the reverse was the case when alum was either in equal quantity or greater amount than MO seed powder in combination. In practical terms, this indicates that when using *Moringa oleifera* alongside alum in water purification, the optimum combination should not necessitate further chemical addition for pH correction. This means that the quantity of alum in the combination should not exceed the quantity of MO seed powder. The quantity of alum should be based on and should be a percentage of the MO dosage suited for the water in question. Presently, 800 mg/L of *Moringa oleifera* seed powder was found suitable for the water sample. Considering only pH as a determining factor for selection of optimum combination, when 20% of this weight was replaced by alum and when 40% of the same weight was replaced by alum, the pH values for the settled waters were respectively 7.13 and 7.11 which are within the WHO recommended range. All the reduction in pH values were corrected using the household filter and all the filter

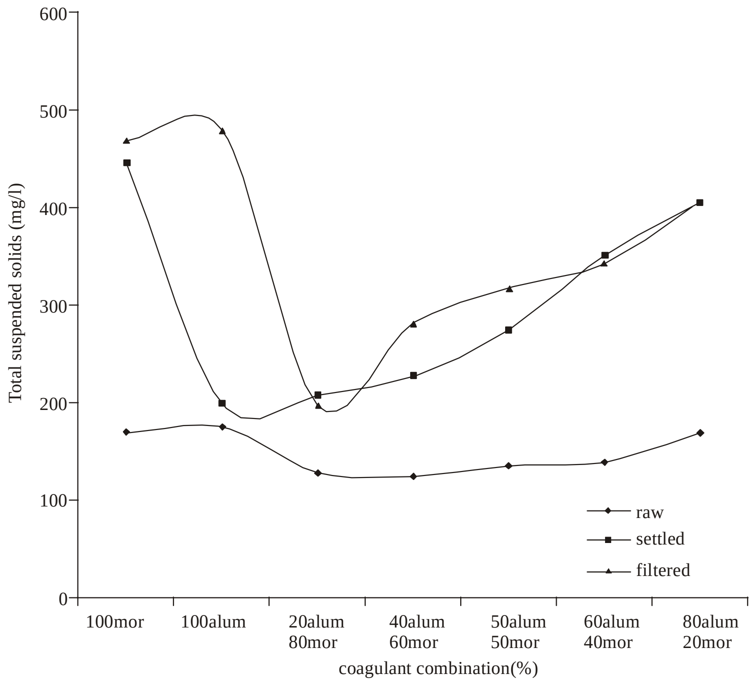

Fig. 2: Plot of total dissolved solids versus coagulant combinations

effluent samples had pH values ranging between 6.67 to 8.1.

Generally there were increments in the values of total dissolved solids (tds) in the settled water above the raw water values as can be seen in Fig. 2. The increments in tds values for the samples into which MO was added (in varying quantities) were higher than the sample with only alum added. The alum only sample had a total dissolved solids (tds) increment of only 13.7% while the increments for the *Moringa* only as well as *Moringa*-alum coagulated samples had a minimum value of 61.1% for (640 mg/L of MO and 160 mg/L of alum) to 162% for 800 mg/L of MO coagulated water. These much increments may have been accentuated by the MO seed powder itself.

When only MO seed powder was added to the water to the tune of 800 mg/L for a settling period of 3 h the residual turbidity in the settled water was 15.1NTU from a raw water sample of 99.10 NTU (Fig. 3). This is a reduction of 84.8%. When this settled effluent was passed a filter media an overall turbidity removal of 92.13% was achieved leaving a residual turbidity of 7.8 NTU. Treatment of water of turbidity 99.1 NTU with 800 mg/L of alum had a settled water residual of 60.3 NTU (39.15%) and an overall system removal of 79.6% (20.20) NTU turbidity residual after the water had passed through the slow sand filter. This result shows that a greater quantity of aluminium sulphate than MO seed powder is needed to treat water of the same turbidity and source although the retention period for the treatment with alum only was 2 h. Considering the removal of turbidity per unit time, the MO seed powder treatment has a removal rate of 28 NTU/h while the alum - only treatment had a removal rate of 19.4 NTU/h. This shows one of the advantages of using the MO seed powder over the aluminium sulphate as a coagulant. The MO seed powder is cheaper and yields a higher turbidity removal rate as an equal weight of aluminium sulphate.

Employing the use of 640 mg/L of alum and 160 mg/L of MO seed powder as a combined coagulant, the raw water turbidity of 99.10 NTU was reduced to settled water turbidity of 15.8 NTU (84.1%) a lower value of turbidity was obtained from the filter effluent as 9.30 NTU. A settling tank removal efficiency of 90.93% was obtained on using 480 mg/L of alum and 320 mg/L of MO seed powder. This efficiency was increased to 93.55% after the passage through the filter media. Application of equal weights of alum and MO seed powder (400 mg/L each) reduced the raw turbidity from raw water value of 99.2 to 9.2 mg/L (90.7%). The filter media reduced this residual value further to 5.4 NTU (94.56% removal efficiency) which in lower than the WHO recommended value of 10 NTU. A reduced alum concentration of 320

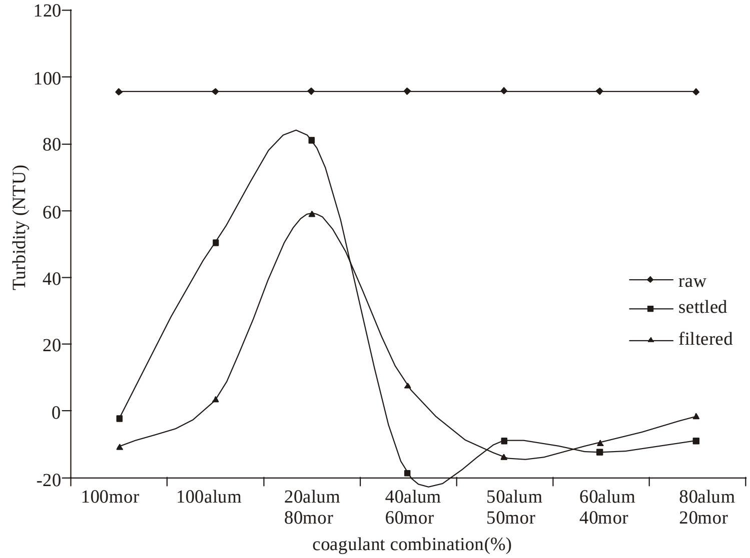

Fig. 3: Plot of turbidity versus coagulant concentartion

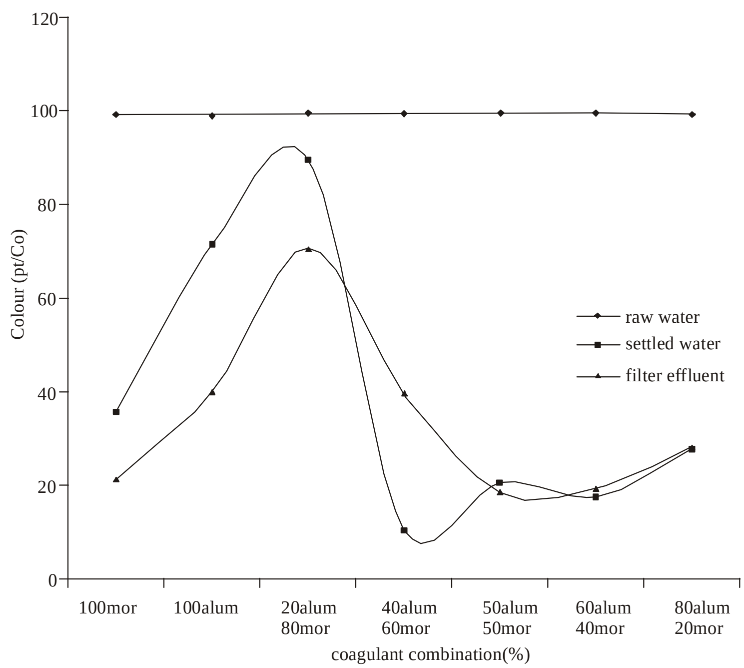

Fig. 4: Plot of colour versus coagulant concentration

and 480 mg/L of MO seed powder combination gave a residual filtered turbidity of 1.00 NTU from a raw water of turbidity value of 99.2 NTU. This is a turbidity removal efficiency of 98.99%.The use of 160 mg/L of alum and 640 mg/L of MO seed powder removed only 12.7% of turbidity in the settling tank and achieved an overall system removal efficiency of 31.6%.

The highest value of colour removal achieved was of 89.35% and it was accomplished by a combination of 480 mg/L of *Moringa oleifera* seed powder and 320 mg/L of aluminium sulphate.

Other combinations also gave well to fairly good settling tank colour removal efficiencies. These include *Moringa* seed powder only (64.1%); 480 mg/L of alum

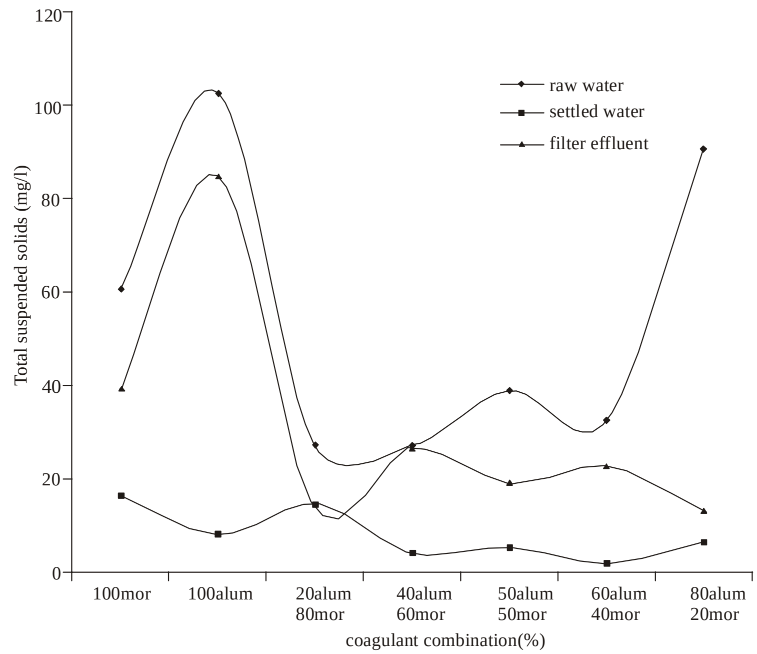

Fig. 5: Plot of total suspended solids

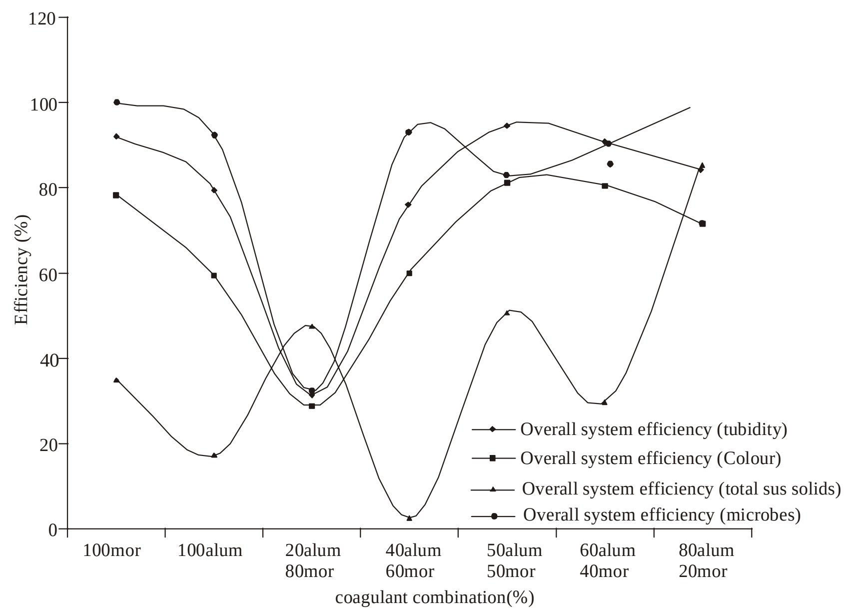

Fig. 6: The overall system efficiency

and 320 mg/L of Moringa oleifera seed powder (80.53)%; 400 mg/L of *Moringa oleifera* seed powder and 400 mg/L of alum (79.25%) and 640 mg/L of alum and 160 mg/L of *Moringa oleifera* seed powder (71.62%) (Fig. 4).

The settling tank yielded good suspended solids removal efficiencies. The *Moringa* only treated sample had a total suspended solids removal efficiency of 72.5% having reduced the total suspended solids concentration from a raw water value of 45.6 to 12.4 mg/L. The maximum total suspended solids removal was achieved by the 480 mg/L of alum plus 320 mg/L MO combination to the efficiency level of 93.94%. The settled water had a residual suspended solids value of 148 mg/L. The lowest total suspended solids removal efficiency was from the 160 mg/L alum plus 640 mg/L MO seed powder combination as 46.4% showing a residual settled water suspended solids value of 10.98 mg/L (Fig. 5).

Some of the combinations gave good water purification results which include high turbidity and microbial removal (Fig. 6) for overall system efficiency. For the use of only *Moringa* as the sole coagulant (i.e., 800 mg/L) 100% microorganism removal (i.e., 0 residual total coliform count) was achieved. The same result was obtained (using the combination of 640 mg/L of aluminium sulphate plus 160 mg/L *Moringa oleifera* seed powder) for the filter effluent. When 800 mg/L of alum was employed as the coagulant dose for the turbid water sample, 92.37% of total coliform count removal resulted. Other combinations that gave good results of 92.96, 90.12 and 82.8% microbial removal were 320 mg/L of alum plus 480 mg/L of *Moringa oleifera*; 480 mg/L of alum plus 320 mg/L of *Moringa oleifera* and 400 mg/L of alum plus 400 mg/L of *Moringa oleifera* respectively. This result is in agreement with Salvato (1992) and Faust and Aly (1998) that when coagulation and filteration systems are managed properly, removal of 90.99% of bacteria and viruses are expected. (WHO, 1997) also reported that operated slow sand filter pathogen removal may exceed 99%.

Establishing optimum coagulant combination: Of all the combinations, only the Moringa only, 160 mg/L alum plus 640 mg/L MO and 320 mg/L alum plus 480 mg/L MO samples did not alter the pH of the settled water. However, despite the alteration in the pH values, the filter medium stabilized these values to the acceptable WHO range of 6.5 to 8.5. Basing on the pH and turbidity results for settled and filtered water, more than one of the combinations gave satisfactory results. From the stand point of pH, for settled water, the *Moringa* only, 640 mg/L MO plus 160 mg/L alum and 480 mg/L MO plus 320 mg/L alum did not alter the pH from the acceptable range. When a filter medium is not to be used for water treatment at the household level, alum can be used as a coagulant aid to MO seed powder. This is because the presence of the MO acts to neutralize any pH alteration the alum may have introduced into the water. The use of a slow sand filter polished the settled tank effluent to the desired turbidity level from an undesirable level. When only *Moringa oleifera* was used for coagulant from a value of 15.1NTU to 7.8NTU. This was also experienced for 640 mg/L alum plus 160 mg/L MO as well as 320 mg/L alum plus 480 mg/L MO. Some of the settled tank effluent turbidity values were within the acceptable WHO limit (10 mg/L) as was the case with 400 mg/L MO plus 300 mg/L alum and 480 mg/L alum and 320 mg/L MO . The result also shows that with a particular weight of MO seed powder accomplishes more treatment than an equal weight of aluminium sulphate.

Five of the seven used coagulant combinations gave acceptable turbidity reduction i.e., below 10 NTU. When *Moringa oleifera* seed powder was used as the sole coagulant, a filter was needed to obtain an acceptable turbidity value of 7.8 NTU but there was no need for pH adjustment or correction. The above was the case for the 480 mg/L MO plus 320 mg/L alum combination although a lower filter turbidity effluent was obtained. Throughout the experiment, the total coagulant weight was kept constant at 800 mg/L of water. The three other combinations that gave acceptable turbidity reduction values were equal weight of alum and *Moringa oleifera* seed powder (i.e., 400 mg/L of alum plus 400 mg/L of MO); 480 mg/L of alum plus 320 mg/L of MO as well as 640 mg/L of alum plus 160 mg/L of MO seed powder. These mentioned three combinations needed pH adjustment which was accomplished using the filter medium, although for the first two, the settling tank gave a turbidity effluent of less than 10 NTU. From the foregoing, the use of *Moringa oleifera* seed powder as a sole coagulant is upheld but a household filter is necessary if the detention period is three hours or less. The need of filter may be eliminated if the detention period is extended.

While considering the combinations, the advantage of the inclusion of alum is suggested as a coagulant aid to MO seed powder i.e. that the quantity of MO should exceed that of alum. This will eliminate the used for pH adjustment as well as shorten the settling time in addition to saving cost. From the work done, the 480 mg/L MO plus 320 alum combinations is considered the optimum. This combination means that for a given optimum weight of *Moringa oleifera* seed powder for any turbid water, 40% of that weight should be removed and replaced with an equal weight of alum. This will hasten water coagulation and disinfection in the home.

CONCLUSION

Moringa oleifera seed powder can be used in treating household drinking water either as a sole coagulant or in combination with alum (using the alum) as a coagulant aid. The settling time for the MO seed powder is longer than that of the combined coagulants if the same results are to be obtained. The recommended ratio for the combined coagulant dose is 60% MO seed powder and 40% alum. Incorporating a filter medium into household water treatment will help improve the water quality. The use of MO seed powder is made economical because same weight of MO seed powder accomplishes more treatment than an equal weight of alum.

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